

Sonderdruck aus Bd. 30 (1985), H. 4, S. 264-279

Meeresforschung · Reports on Marine Research

Berichte der Deutschen Wissenschaftlichen Kommission für Meeresforschung

VERLAG PAUL PAREY · SPITALERSTRASSE 12 · D-2000 HAMBURG 1

Alle Rechte, auch die der Übersetzung, des Nachdrucks, der photomechanischen Wiedergabe und Speicherung in Datenverarbeitungsanlagen, vorbehalten. © 1985 Verlag Paul Parey, Hamburg und Berlin

Distribution, abundance and diurnal migration of macrozooplankton in Antarctic surface waters

By U. PIATKOWSKI

Alfred-Wegener-Institut für Polarforschung, Bremerhaven

Ms. received 10 Sept. 1985

Ms. accepted 8 Oct. 1985

Abstract

Macrozooplankton was collected on 65 stations in the surface waters off the Antarctic Peninsula during the Anglo-German Antarctic expedition in February 1982. Composition, abundance and geographical distribution of the major constituents were analyzed. Most abundant species were the euphausiids *Euphausia superba* and *Thysanoessa macrura* and the salp *Salpa thompsoni*.

Vertical distribution and diurnal migration of the predominant macrozooplankton species were investigated on two transects in the southern Drake Passage and across the Bransfield Strait, as well as on two time stations in the vicinity of Elephant Island. Stratified RMT 8 hauls showed that *Euphausia frigida*, *Euphausia triacantha* and *Salpa thompsoni* migrated to the surface during the night, whereas the other taxa did not migrate.

Kurzfassung

Verbreitung, Häufigkeit und tagesperiodische Wanderungen des Makrozooplanktons im Oberflächenwasser der Antarktis

Makrozooplankton wurde an 65 Stationen im Oberflächenwasser nahe der Antarktischen Halbinsel während der Britisch-Deutschen Antarktis-Expedition im Februar 1982 gesammelt. Die Zusammensetzung sowie Häufigkeit und geographische Verbreitung der hauptsächlich vorkommenden Arten wurden untersucht. Häufigste Arten waren die Euphausiiden *Euphausia superba* und *Thysanoessa macrura* und die Salpe *Salpa thompsoni*.

Vertikalverteilung und tagesperiodische Wanderungen der vorherrschenden Arten wurden auf zwei Stationschnitten in der südlichen Drake-Passage und durch die Bransfield-Straße sowie auf zwei Dauerstationen in der Nähe von Elephant Island untersucht. Stufenhols mit dem RMT 8 zeigten für *Euphausia frigida*, *Euphausia triacantha* und *Salpa thompsoni* eine deutliche Vertikalwanderung zur Wasseroberfläche in der Nacht, während die anderen Arten keine Vertikalwanderung zeigten.

Introduction

Previous studies on the distribution of Antarctic macrozooplankton concentrated mainly on one species, *Euphausia superba*, the Antarctic krill, because of its key position within the Antarctic ecosystem. Most investigations on macrozooplankton species other than krill were based on the plankton collections of various great Antarctic expeditions such as the "Discovery" expeditions.

Several authors (e.g. BARNARD 1932; JOHN 1936; DAVID 1958; FOXTON 1966) gave detailed descriptions on single groups (amphipods, euphausiids, chaetognaths, salps), but

U.S. Copyright Clearance Center Code Statement: 0341-6836/85/3004/0264 \$ 02.50/0

Meeresforsch. 30 (1985), 264–279

© 1985 Verlag Paul Parey, Hamburg und Berlin

ISSN 0341-6836 / InterCode: MEERDW

only few analyzed the macrozooplankton composition as a whole (e.g. MACKINTOSH 1934; HARDY and GUNTHER 1936). More recently MILLER (1985) described macroplankton groups off two subantarctic islands, and HOPKINS (1985) analyzed the zooplankton community of the Croker Passage near the Antarctic Peninsula. However, information on distribution patterns of macrozooplankton species, which occur together with krill, is still very sparse.

During the Anglo-German Antarctic expedition on RRS "John Biscoe" in February 1982 (HEMPEL and HEYWOOD 1982) macrozooplankton was collected from surface waters (haul depth ≤ 200 m) off the Antarctic Peninsula.

The present study provides data on the distribution patterns of those macrozooplanktonic-micronektonic species, which were most abundant numerically and in terms of biomass. Furthermore, the data on the distribution of macrozooplankton were compared with hydrographic data collected during the sampling period (HEYWOOD 1985) to see if there was any relationship between the distribution of macrozooplankton species and the different water masses.

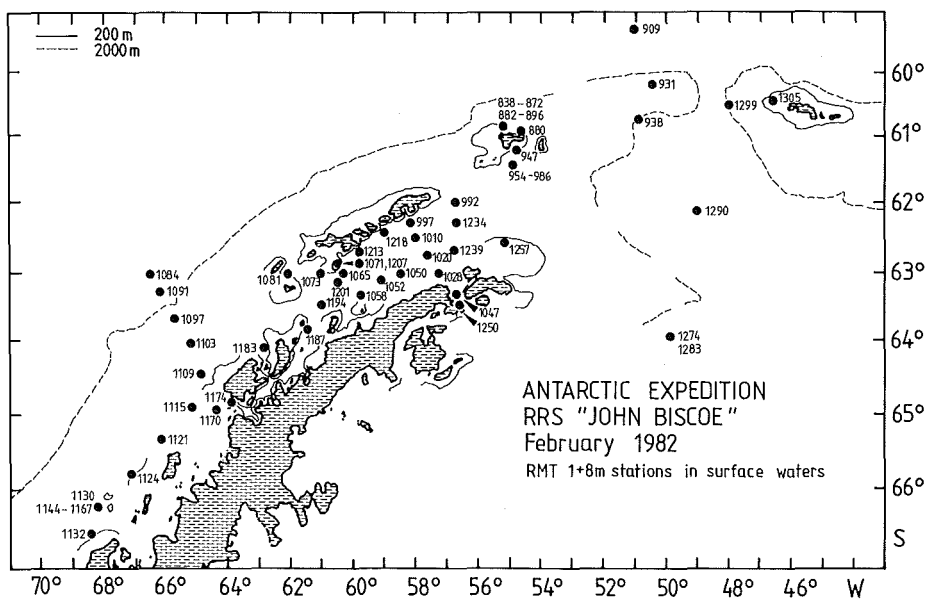


Fig. 1. Locations of sampling stations in the investigated area

Material and methods

Field sampling

The investigated area ranged from 46° to 69° W and 59° to 67° S with emphasis on the Bellingshausen Sea, the Bransfield Strait and waters off Elephant Island (Fig. 1).

Sampling was carried out with a multiple rectangular midwater trawl (RMT 1 + 8 M), which is described in detail by ROE and SHALE (1979). The RMT 1 + 8 M is an acoustically operated opening and closing net system with three pairs of 0.32 mm (RMT 1) and 4.5 mm (RMT 8) mesh nets. These open and close sequentially, which enables stratified sampling in three successive water layers during one haul. The mouth openings of the nets are approximately 1 m² for the RMT 1 and approximately 8 m² for the RMT 8, varying a little with the towing speed (ROE et al. 1980).

Only samples from surface waters (≤ 200 m haul depth) obtained by the larger RMT 8 were analyzed for this study. A total of 195 samples were taken on 65 stations (Fig. 1). The standard haul was an oblique haul with depth intervals of approximately 200 m to 140 m, 140 m to the thermocline, thermocline to surface, of a towing duration not exceeding 20 minutes in each layer (vessel speed ranged from 1.5 to 3 knots). The position of the thermocline was estimated from preceeding STD recordings (HEYWOOD 1985). Hauling speed was always below 0.3 m/s to avoid damage of animals caught. PIATKOWSKI (1983) gives a synopsis of plankton haul data such as position of stations, accurate haul depths and filtered water volumes.

The displacement volume of each catch was measured on board immediately after the haul. Large animals such as medusae, squid and fish were separated from the catch before preservation in 4 % chalk-buffered seawater formaldehyde solution. Subsamples of 2000 ml were taken of catches exceeding 3000 ml.

Parallel to the plankton sampling, STD recordings were carried out to identify and describe the water masses during the period of investigation (HEYWOOD 1985). The data were used to draw up isotherms of the surface water temperatures into the transect profiles (Figs. 12 to 15) for better interpretation of the macrozooplankton distribution.

Laboratory procedures

The samples were sorted into the taxonomic groups as listed in Table 1. A minimum length or diameter of 7 mm was chosen as lower size boundary for the sorting of organisms from samples. The remaining smaller zooplankton including copepods, ostracods and appen-

Table 1. List of macrozooplankton groups sorted from RMT 8 samples

<i>Euphausia superba</i>	Mysids	Siphonophores
Other Euphausiids	Pteropods	Salps
Hyperiid	Cephalopods	Chaetognaths
Gammarids	Polychaetes	Fish larvae
Decapods	Medusae	Adult Fishes

dicularians, which is not sampled quantitatively by the RMT 8, was not sorted and kept as residual sample.

Of the 15 taxonomic groups sorted, the 6 most abundant were selected for the distribution studies: *Euphausia superba*, other euphausiids, hyperiids, siphonophores, chaetognaths and salps. Rare species ($\text{ind./1000 m}^3 \leq 1$) were not considered. Animals were determined to genus and species level after: MAUCLINE (1980) and KIRKWOOD (1982) for euphausiids, BOWMAN and GRUNER (1973) and DINOFRIO (1977) for amphipods, MOSER (1925) and ALVARIÑO (1981) for siphonophores, and ESNAL (1981) and O'SULLIVAN (1983) for salps.

Chaetognaths were not identified to species level and are treated as one group in this study. HAGEN (1985) gives detailed information on species composition and distribution of the chaetognaths sampled. Siphonophores consisted almost exclusively of the two species *Diphyes antarctica* and *Dimophyes arctica*, however, due to problems in correct identification of damaged specimens, they also were treated as one group, where any identifiable piece of a siphonophore was enumerated (nectophores as well as medusoid individuals).

To illustrate the geographical distribution and abundance of the various groups, the three RMT 8 samples of each surface haul were combined (Figs. 3 to 11). For analyses of vertical distribution, however, the three samples of each haul were evaluated separately (Figs. 12 to 15). The total number of individuals counted as well as filtered water volumes

of the hauls on each of the time stations (Elephant Island North, Elephant Island South and Bellingshausen Sea) were integrated to obtain mean values of relative abundance (ind./1000 m³) for the different groups at these locations.

Samples were also divided into those taken during the day (06–22 h local time) and those taken at night (22–06 h local time).

Hydrography

Only a brief description of the general hydrographic features and currents in the sampling area is given here (Fig. 2). For more details see CLOWES (1934) and DEACON (1937), and more recently ANON. (1983a, b).

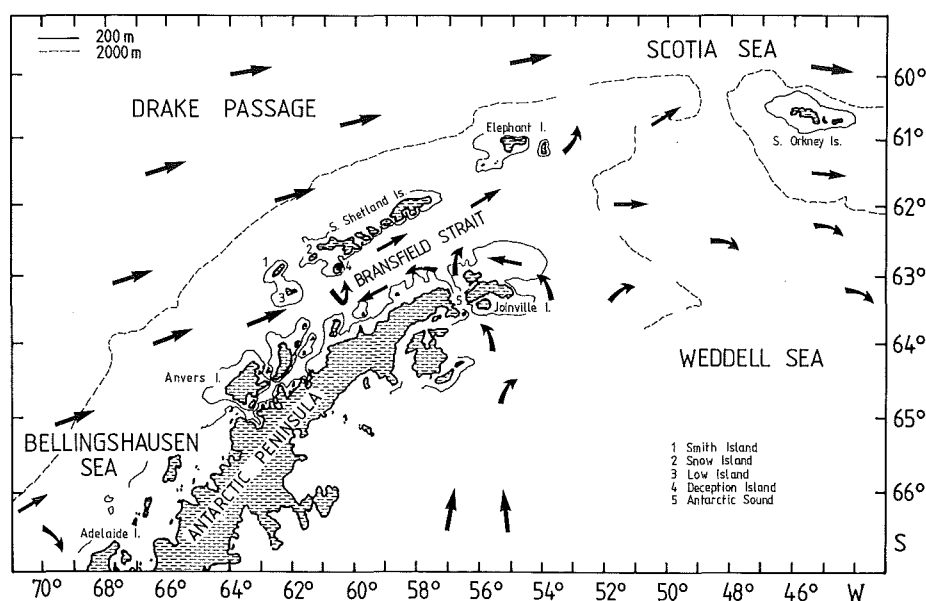


Fig. 2. Geographical locations and main surface currents in the area of investigation

The surface waters off the Antarctic Peninsula are mainly influenced by Bellingshausen Sea water, Weddell Sea water and Antarctic surface water of the southern Drake Passage and the Scotia Sea, the latter forming the northern part of the investigated area. Salinity and temperature here were relatively high during the sampling period (34.0 to 34.6 ‰; 0.3 to 2.8 °C). The south-western parts are governed by water masses of Bellingshausen Sea origin, which flow along the continental slope in a north-easterly direction. During the austral summer, ice melt gradually lowers the salinity, whereas solar radiation raises the temperature (33.1 to 34.7 ‰; –1.6 to 1.4 °C during the period of investigation). Between Smith, Low and Snow Islands the southern branch of these water masses enters the Bransfield Strait, where it spreads north and south of Deception Island. The main surface current in the Bransfield Strait, with water masses originating in the Bellingshausen Sea, flows along the southern side of the South Shetland Islands in a north-easterly direction. The more saline and colder Weddell Sea water (33.5 to 34.7 ‰; –1.7 to 0.3 °C in February 1982) enters the Bransfield Strait after rounding Joinville Island, and through the Antarctic Sound, where it forms a countercurrent which flows southwards along the Antarctic

Peninsula. A portion also spreads northwards across the Strait. Where these currents meet somewhere in the middle of the Bransfield Strait they cause meanders, gyres and complex mixing zones, which have a large effect on the plankton distribution.

Results

Geographical distribution and abundance

Zooplankton assemblages of the nearshore stations differed from those farther offshore in having a larger biomass as well as a higher density of several species. Areas with highest macrozooplankton concentrations were found north of Elephant Island (4710 ml/1000 m³) and in the Bellingshausen Sea north of Adelaide Island (5377 ml/1000 m³), where the largest of all catches was recorded (Station 1149). Stations in the Bransfield Strait had the largest species diversity. At most stations one or two species were numerically dominant, usually *Euphausia superba* and *Salpa thompsoni*.

Euphausiids

Five species of antarctic euphausiids were identified: *Euphausia superba*, *Euphausia frigida*, *Euphausia triacantha*, *Euphausia crystallophias* and *Thysanoessa macrura*, all known to have a circumpolar distribution south of the Antarctic Convergence. The Antarctic krill, *E. superba* was the dominant species. It was found at all stations (Fig. 3). The maximum density of 14 543 ind./1000 m³ was obtained at Station 1149 in the Bellingshausen Sea, north of Adelaide Island. The second most abundant euphausiid species was *T. macrura*, also caught at each station. It had a uniform distribution in the area investigated (Fig. 4). The richest catch (1182 ind./1000 m³) was made at Station 1050 in the southern Bransfield Strait within the upper 50 m. *E. frigida* had its main distribution in the

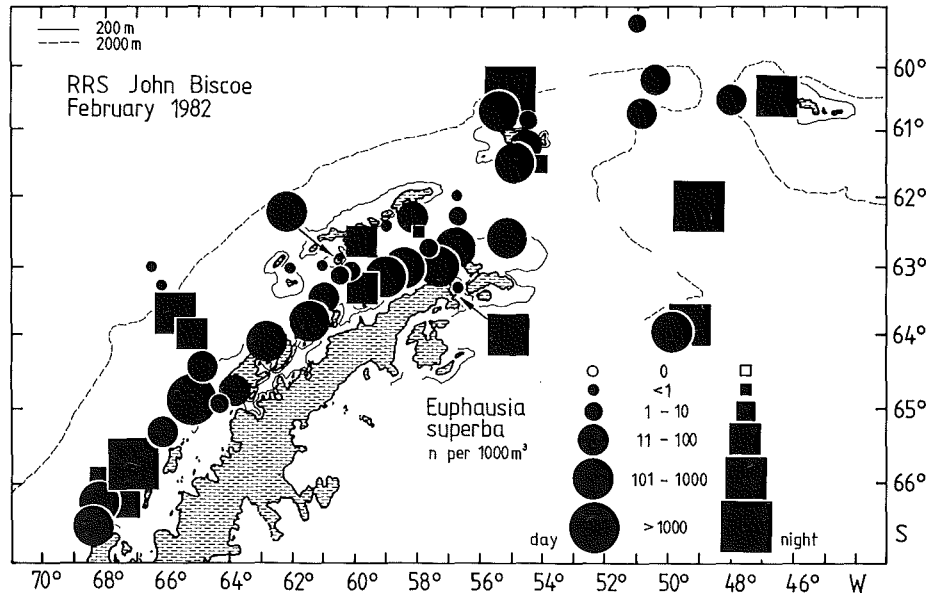


Fig. 3. Distribution and relative abundance of *Euphausia superba* in waters off the Antarctic Peninsula

southern Drake Passage (Station 1097) and around Elephant Island (Fig. 5). The highest abundance (81 ind./1000 m³) was recorded at a station to the north of Elephant Island in the water layer between 140–200 m. *E. triacantha* had a distribution pattern similar to that of *E. frigida* (Fig. 6). The species occurred sporadically. Considerable catches were made in

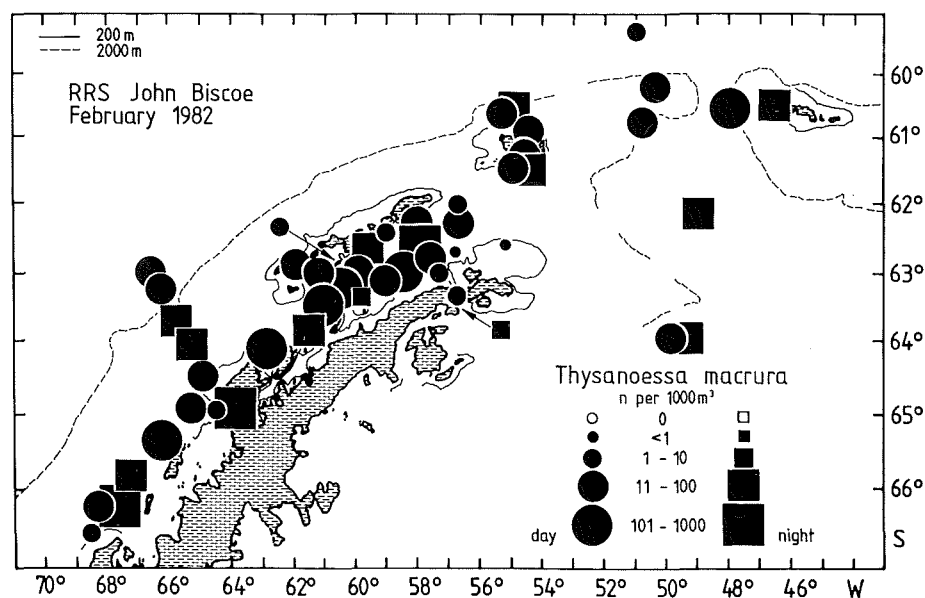


Fig. 4. Distribution and relative abundance of *Thysanoessa macrura* in waters off the Antarctic Peninsula

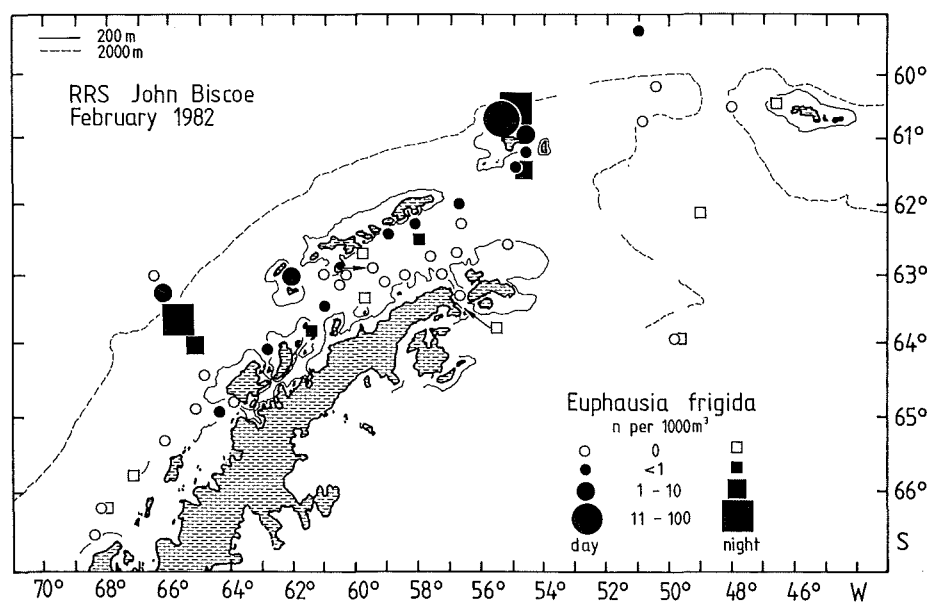


Fig. 5. Distribution and relative abundance of *Euphausia frigida* in waters off the Antarctic Peninsula

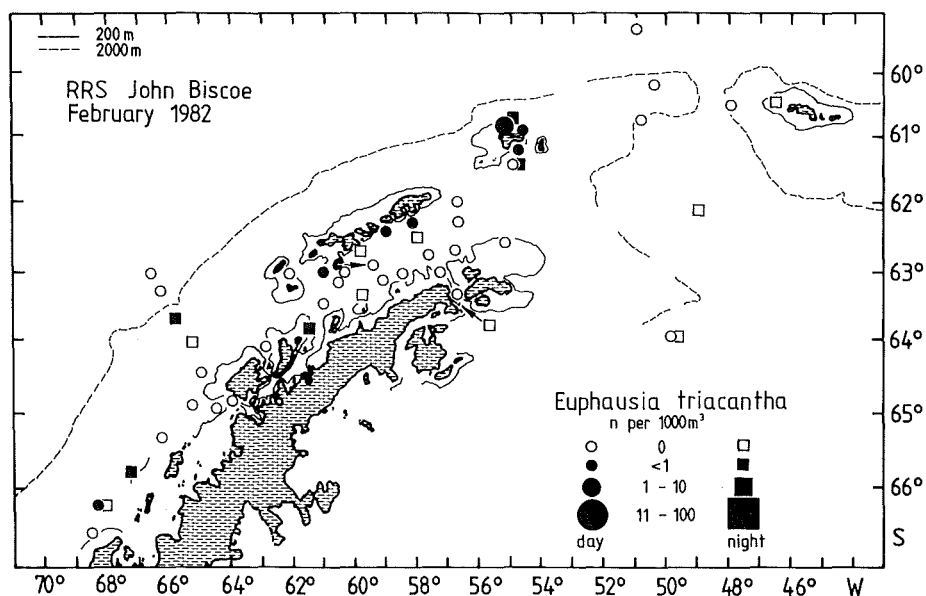


Fig. 6. Distribution and relative abundance of *Euphausia triacantha* in waters off the Antarctic Peninsula

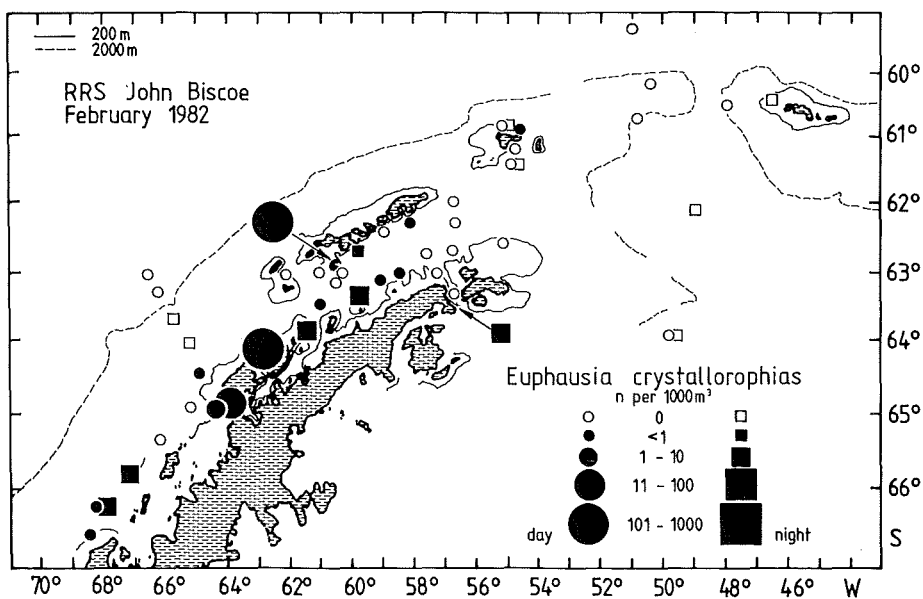


Fig. 7. Distribution and relative abundance of *Euphausia crystallorophias* in waters off the Antarctic Peninsula

the waters off Elephant Island and in the northern Bransfield Strait. A maximum concentration of only 8 ind./1000 m³ was found in the surface waters to the north of Elephant Island. The distribution of *E. crystallorophias* (Fig. 7) was restricted to nearshore

regions. The highest concentration of 904 ind./1000 m³ was obtained from the shallow water station inside the Deception Island caldera (Station 1071).

Amphipods

Themisto gaudichaudii was the most frequent hyperiid amphipod. The maximum concentration (810 ind./1000 m³) was found at Station 1121 in the northern Bellingshausen Sea (Fig. 8). Other hyperiid amphipods found, were *Cylopus magellanicus*, *Cylopus lucasii*, *Hyperoche medusarum*, *Primno macropa*, *Hyperia* sp., *Hyperiella dilatata*, *Hyperiella macronyx*, *Vibilia propinqua* and *Scina* sp. Gammarids species encountered belonged to the genera *Eusirus* and *Orchomene*. Compared to *T. gaudichaudii*, all above mentioned amphipods occurred seldomly (≤ 1 ind./1000 m³).

Chaetognaths

Higher densities of chaetognaths were found mainly south of Elephant Island and in the northern Bransfield Strait (Fig. 9), where the maximum concentration (79 ind./1000 m³) was recorded in a 145–200 m layer (Station 1234). According to HAGEN (1985) *Eukrobia hamata* and *Sagitta gazellae* were the most abundant chaetognath species in the surface waters.

Siphonophores

Oceanic surface waters off the continental slopes were the main habitat of this group, although the maximum concentration (286 ind./1000 m³) was found in the shallow Deception Island caldera (Station 1071) in less than 135 m water depth (Fig. 10). The prevailing members of this group were *Diphyes antarctica* and *Dimophyes arctica*, of which nectophores predominated.

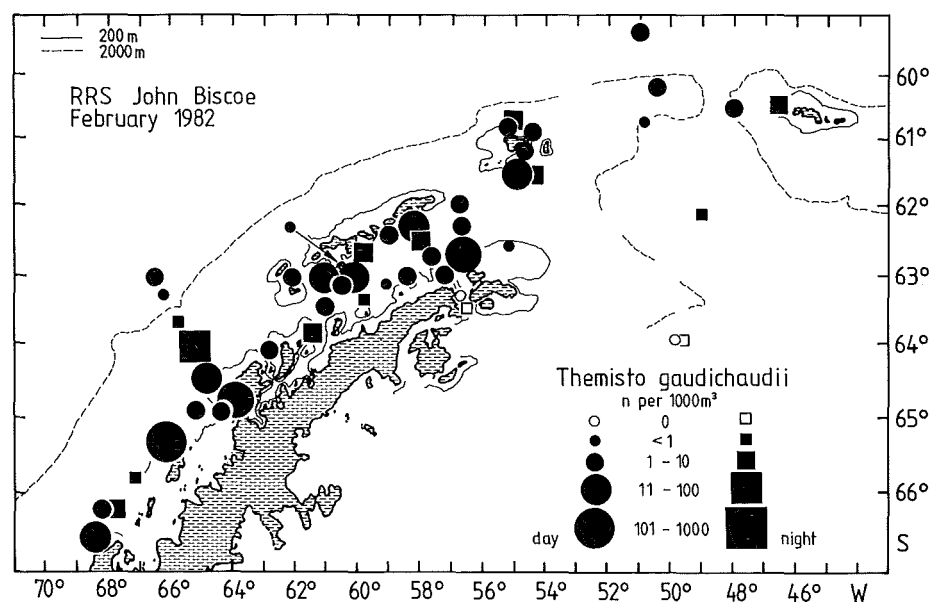


Fig. 8. Distribution and relative abundance of *Themisto gaudichaudii* in waters off the Antarctic Peninsula

Salps

The only salp found, was *Salpa thompsoni*. Like the siphonophores, *S. thompsoni* is a typical inhabitant of the oceanic waters, being very abundant at stations in the southern

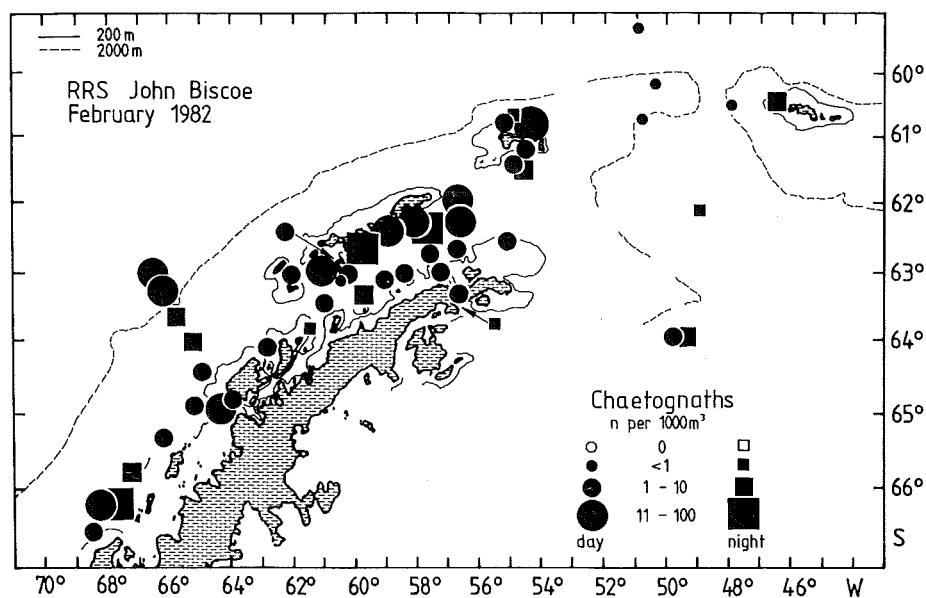


Fig. 9. Distribution and relative abundance of chaetognaths in waters off the Antarctic Peninsula

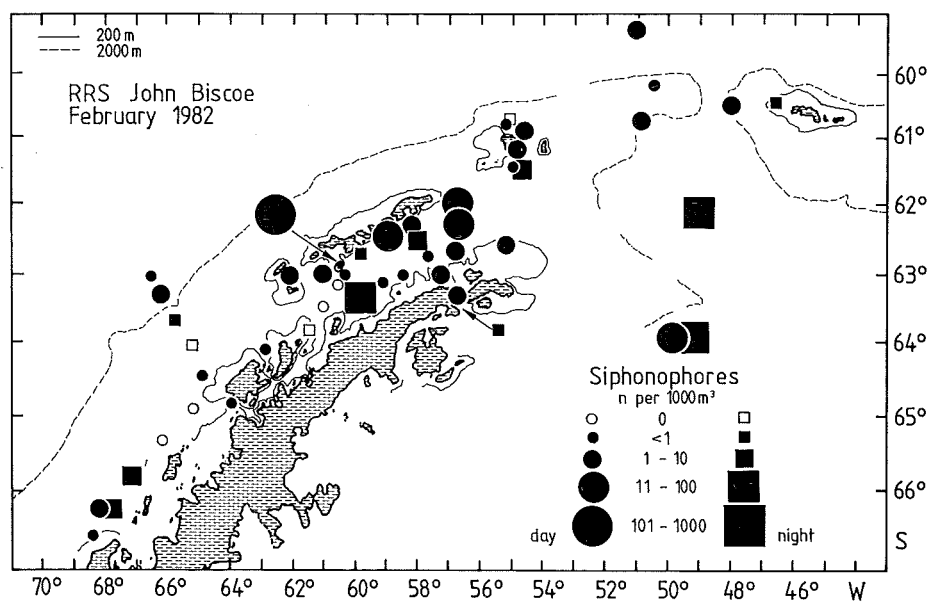


Fig. 10. Distribution and relative abundance of siphonophores in waters off the Antarctic Peninsula

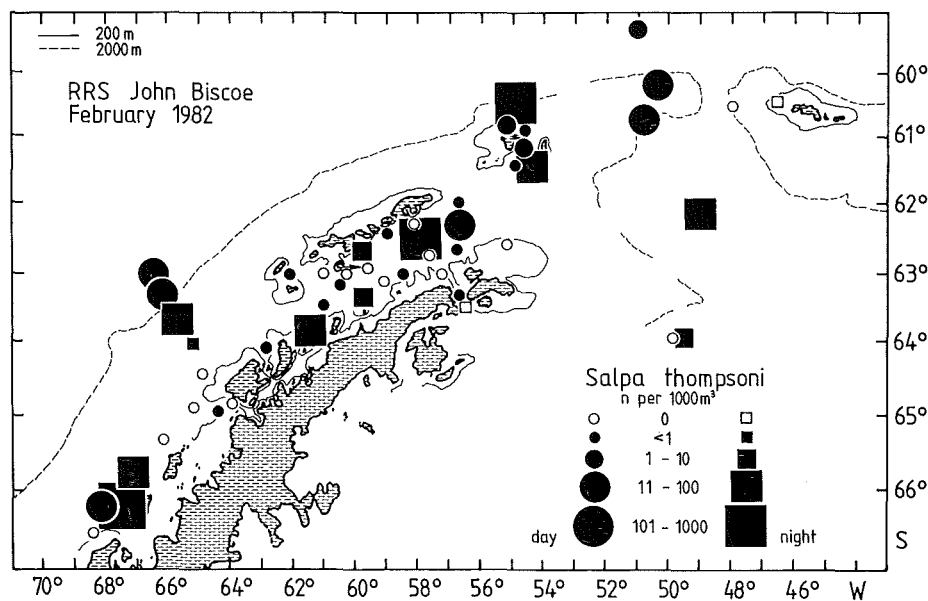


Fig. 11. Distribution and relative abundance of *Salpa thompsoni* in waters off the Antarctic Peninsula

Drake Passage and in the vicinity of Elephant Island. A maximum concentration of 762 ind./1000 m³ was recorded at Station 865 north of Elephant Island (Fig. 11).

Other macrozooplankton groups such as the medusae, pteropods, cephalopods, polychaetes, decapods and mysids did not occur in sufficient numbers (≤ 1 ind./1000 m³) to allow descriptions of their distribution pattern. Maximum and mean concentration of each taxon investigated as well as the frequency of occurrence are shown in Table 2. Table 3 gives the range of water depths and water temperature, in which they occurred.

Vertical distribution and diurnal migration

The vertical distribution of the zooplankton groups could be investigated due to the stratified sampling. Two transects (Figs. 12 and 13) and two time stations (Figs. 14 and 15) were selected to illustrate patterns of vertical distribution and diurnal migration in addition to the geographical distribution.

Figure 12 shows vertical patterns along a transect from the southern Drake Passage down to Anvers Island. The abundance of the euphausiids *E. superba* and *E. crystallorophias* increased towards the shelf of the Antarctic Peninsula, whereas the abundance of *S. thompsoni* decreased. *T. macrura*, *T. gaudichaudii* and chaetognaths were evenly distributed at all stations and did not show a diurnal migration. The main phytoplankton feeders *E. superba* and *S. thompsoni* were the only species with dense concentrations in the surface layer during the night. The depth distribution of *E. triacantha* and *E. frigida* indicated patterns of diurnal migration. They ascended to the surface layers during the night and remained in waters deeper than 140 m and 200 m during daytime. *E. frigida* occurred only in samples collected at night.

Fig. 13 shows a sequence of stations across the Bransfield Strait. Inside the Antarctic Sound (Station 1047 and 1250) which connects the Bransfield Strait with the northern Weddell Sea, rich samples of *E. superba* and *E. crystallorophias* were caught during the

Table 2. Maximum and mean numbers of each taxon investigated and frequency of occurrence (n = 65 stations)

Taxon	Concentration (ind./1000 m ³)		Occurrence %
	Maximum	Mean ¹	
<i>Euphausia superba</i>	14 543	576	100
<i>Thysanoessa macrura</i>	1 182	66	100
<i>Euphausia frigida</i>	81	9	44
<i>Euphausia triacantha</i>	8	1	28
<i>Euphausia crystallorophias</i>	904	128	30
<i>Themisto gaudichaudii</i>	810	14	94
Chaetognaths	79	8	97
Siphonophores	286	13	80
<i>Salpa thompsoni</i>	762	41	69

¹ Only positive hauls considered.

Table 3. Ranges of water depth and water temperature, in which the macrozooplankton taxa occurred

Taxon	Water depth		Water temperature
<i>Euphausia superba</i>	113–3387 m	–1.70 to 2.65 °C	($\Delta T = 4.35$ °C)
<i>Thysanoessa macrura</i>	113–3387 m	–1.70 to 2.65 °C	($\Delta T = 4.35$ °C)
<i>Euphausia frigida</i>	247–3387 m	–1.27 to 1.91 °C	($\Delta T = 3.18$ °C)
<i>Euphausia triacantha</i>	247–2410 m	–1.62 to 1.65 °C	($\Delta T = 3.27$ °C)
<i>Euphausia crystallorophias</i>	113–1345 m	–1.62 to 2.20 °C	($\Delta T = 3.82$ °C)
<i>Themisto gaudichaudii</i>	113–3387 m	–1.62 to 2.65 °C	($\Delta T = 4.27$ °C)
Chaetognaths	113–3387 m	–1.70 to 2.65 °C	($\Delta T = 4.35$ °C)
Siphonophores	113–3387 m	–1.70 to 2.65 °C	($\Delta T = 4.35$ °C)
<i>Salpa thompsoni</i>	200–3387 m	–1.70 to 2.42 °C	($\Delta T = 4.12$ °C)

night (Station 1250), whereas Station 1047 during the day produced only a few specimens of *E. superba* and no *E. crystallorophias*. The euphausiid *T. macrura* was again evenly distributed with considerable numbers at all stations. Chaetognaths and siphonophores were present at all stations, but they occurred more frequently in the deeper layers of the surface water. *E. triacantha* and *E. frigida* were only caught at stations in the north-western part of the Bransfield Strait. Like *T. gaudichaudii*, they were totally absent in the Antarctic Sound. *E. superba* occurred in considerable quantities in the southern part of the Bransfield Strait, whereas *S. thompsoni* was only sporadically found in this region.

Two time stations were carried out in the vicinity of Elephant Island, one oceanic station in the southern Drake Passage (water depth approximately 2000 m) located north of the island (Fig. 14), the other south of Elephant Island (Fig. 15) in a shallower region (water depth ≤ 1000 m).

E. superba was considerably more abundant north of the island. No diurnal migration was detected for *E. superba* at both stations. *E. triacantha* and *E. frigida* were fairly abundant north of Elephant Island, whereas in the south they were scarce. At night, however, *E. frigida* occurred in concentrations above 10 ind./1000 m³. *T. macrura* was again evenly distributed at both time stations, while diurnal variations did not occur. *T. gaudichaudii* showed a distribution similar to that of *T. macrura*, but was present at lower concentrations. Chaetognaths and siphonophores showed no diurnal migration at both time stations. Their abundance increased with depth. The most significant differences occurred in the geographical and vertical distributions of *S. thompsoni*. The oceanic time station north of Elephant Island produced very rich samples, whereas those of the southern

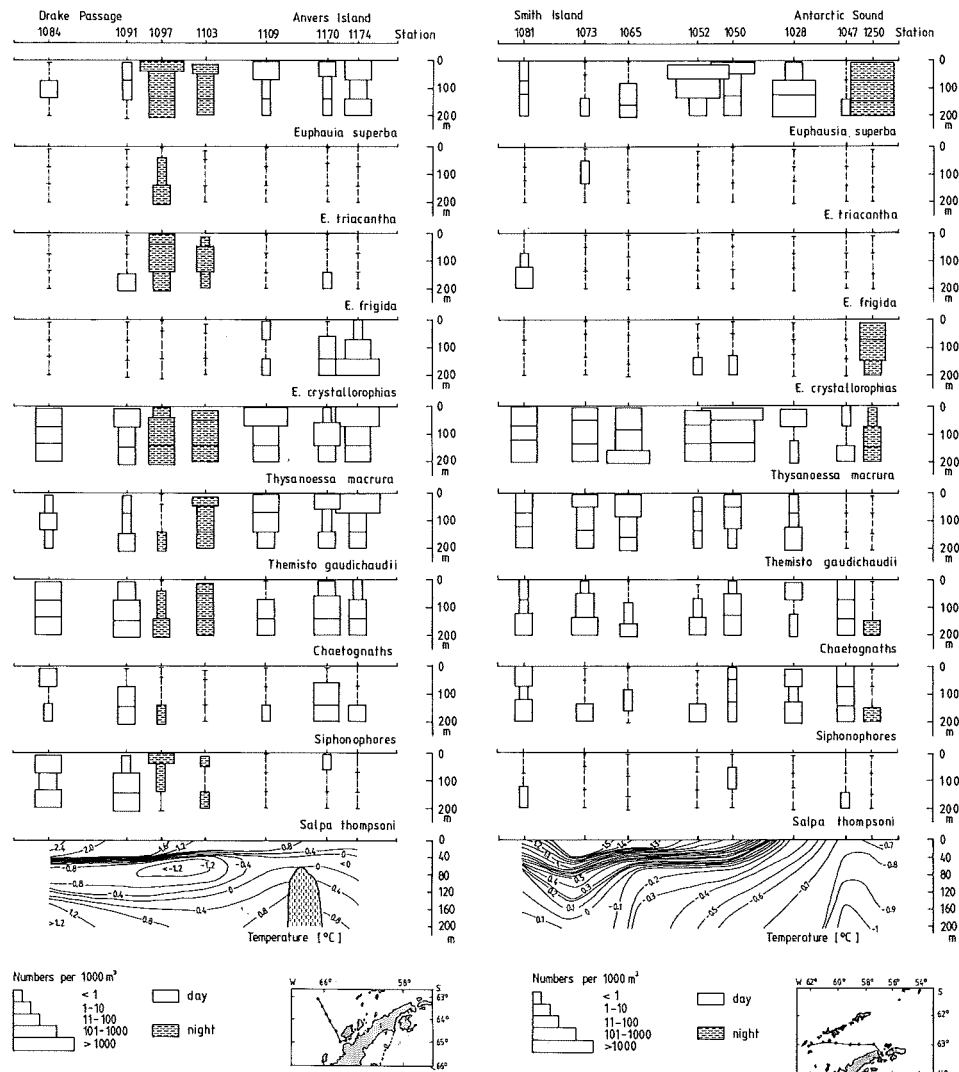


Fig. 12. Left. Vertical distribution and relative abundance of macrozooplankton groups in the southern Drake Passage and off Anvers Island in February 1982. – Fig. 13. Right. Vertical distribution and relative abundance of macrozooplankton groups in the southern Bransfield Strait and in the Antarctic Sound

time station were poorer. Night stations with high concentrations just below the surface alternated with daytime stations of low densities.

Discussion

The prevailing macrozooplankton species, *Euphausia superba*, generally showed highest concentrations in the shelf regions (Fig. 3), especially on the northern shelf of the Antarctic Peninsula in the southern Bransfield Strait. This area is characterized by south-westerly

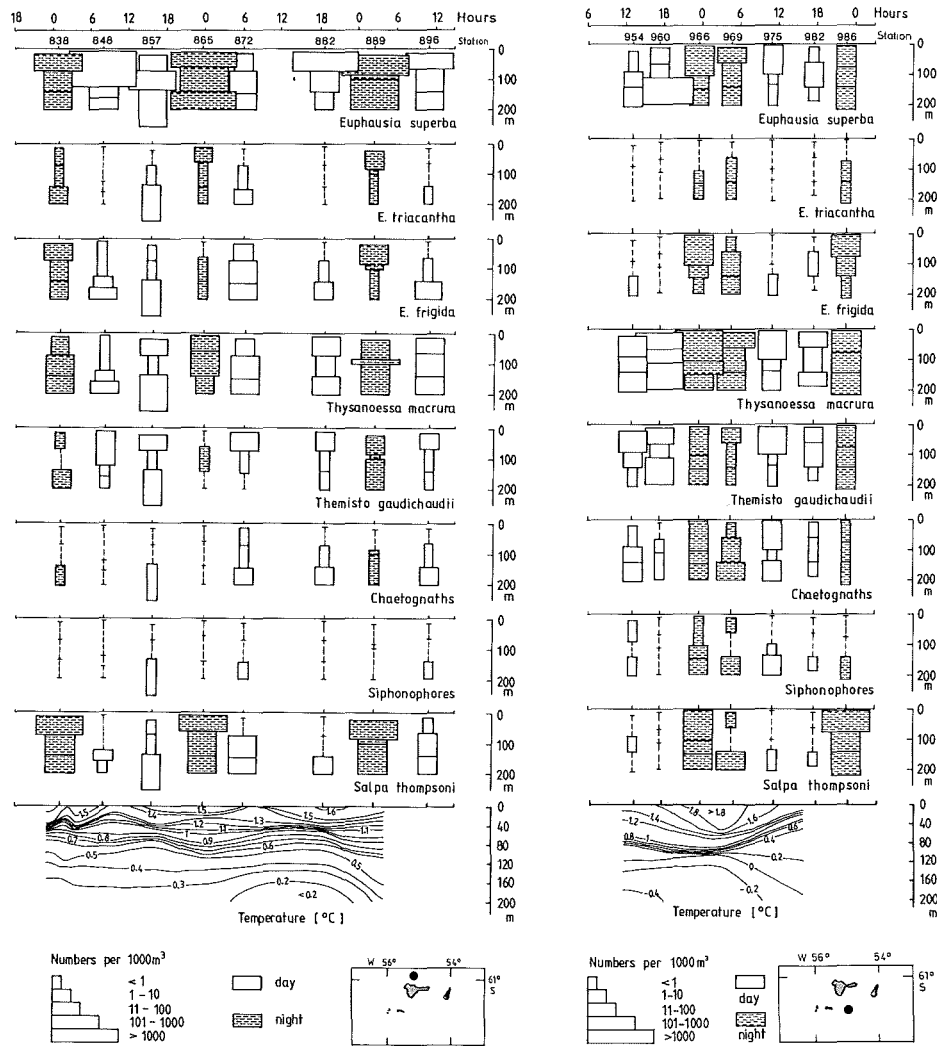


Fig. 14. Left. Vertical distribution and relative abundance of macrozooplankton groups to the north of Elephant Island during a time station in February 1982. – Fig. 15. Right. Vertical distribution and relative abundance of macrozooplankton groups to the south of Elephant Island during a time station in February 1982

currents of Weddell Sea water (ANON 1983b; HEYWOOD 1985). This distribution pattern suggests that *E. superba* prefers Weddell Sea water, which is confirmed by SIEGEL (1985). Surprisingly rich krill samples (4080 ind./1000 m³) were also obtained from oceanic stations in the northern part of the Weddell Sea (water depth ≥ 3000 m). These stations were situated very close to the marginal pack ice zone, an area of high primary productivity, which contains dense diatom aggregations (TRANter 1982; pers. observations). Whenever these aggregations have access to the open water, excellent grazing areas develop for phytoplankton feeders, which likely then explains the increased krill numbers in this specific habitat.

Thysanoessa macrura showed the most uniform distribution pattern of all taxa examined. There was no indication that the species preferred a certain water mass.

Abundance and geographical distribution of *Euphausia frigida* and *Euphausia triacantha* were similar as those reported by WEIGMANN-HAASS and HAASS (1980). Both species are mainly confined to midwater layers of the Westwind Drift, which was already observed for *E. triacantha* by BAKER (1959). Both do not tend to swarm, and they were the least abundant euphausiids. They were totally absent from Weddell Sea waters. Similar observations were made by WITEK et al. (1984) for *E. frigida*. The most southerly occurrence of *E. frigida* was 65°S, and 66°08'S for *E. triacantha*. These ranges exceed those previously reported for *E. frigida* and *E. triacantha*.

The most northerly distribution of *Euphausia crystallorophias* was established by the finding of 4 specimens on the northern shelf of Elephant Island (Fig. 7). In contrast to all other euphausiids this strictly neritic species was thought to occur only in the coastal and shallow regions of the Antarctic continent and some nearby islands. Its appearance near Elephant Island, however, suggests that currents from the northern Bransfield Strait or the northern Weddell Sea transport zooplankton towards Elephant Island. According to JOHN (1936) and more recently KITTEL (1980) *E. crystallorophias* forms dense aggregations similar to *E. superba*. This is confirmed by high concentrations of *E. crystallorophias* which were encountered in the Deception Island caldera (904 ind./1000 m³) and north of Anvers Island (510 ind./1000 m³).

Chaetognaths are usually confined to midwater and deepwater layers, however, large numbers were obtained from the surface waters off the Antarctic Peninsula. This group, which almost exclusively consisted of the two species *Eukrohnia hamata* and *Sagitta gazellae* (HAGEN 1985) showed no obvious correlation to one of the different water masses, neither did the siphonophores nor the amphipod *Themisto gaudichaudii*. However, *T. gaudichaudii* was totally absent in the northern Weddell Sea and in the Antarctic Sound, both characterized by Weddell Sea water.

Salpa thompsoni did not occur in Weddell Sea water. It was fairly abundant in Bellingshausen Sea water and the highest concentrations were found in the surface waters far off the Antarctic Peninsula, which is characterized by Antarctic surface water of the southern Drake Passage (Fig. 11). This is in accordance with previous studies by MACKINTOSH (1934) and FOXTON (1966), who identified *S. thompsoni* as a prevailing component of the oceanic macrozooplankton in the Southern Ocean. *S. thompsoni* was poorly represented at shelf stations. A remarkable feature of *S. thompsoni* is its discontinuous annual variation in abundance, which was already pointed out by FOXTON (1966) and more recently by PIATKOWSKI (1985). Compared to these studies, the abundance of *S. thompsoni* was relatively low in February 1982.

Because *E. superba* frequently occurs in patches (EVERSON 1982), no diurnal migration towards the surface could be concluded, as densities during day and night did not vary significantly (Figs. 14 and 15). It appears more likely that krill went through a diurnal pattern of day-time swarming and night-time dispersion, as suggested by EVERSON (1982; 1984).

Net avoidance, especially pronounced when sampling takes place in patches or swarms, should be excluded as a source of potential impact on the data obtained, because of the large mouth opening (8 m²) of the RMT 8.

E. frigida, *E. triacantha* and *S. thompsoni* showed an obvious migratory pattern, which took them from the Warm Deep Water in day-time to the upper surface layers at night (Figs. 12, 14 and 15). The thermocline, mostly at approximately 70 m depth, did not appear to act as a barrier. This behaviour suggests that these species undertook diurnal migration in response to the prevailing food supply, which YOUNGBLUTH (1976) also found for euphausiids in the California current. Especially *S. thompsoni*, provided with an effective filter mechanism, which enables an efficient feeding on phytoplankton (HARBISON and

McALISTER 1979) showed dense concentrations just below the surface at night. By rapid development and growth under favourable food conditions (phytoplankton bloom), *S. thompsoni* can produce dense aggregations with an enormous biomass. EVERSON (1984) described this way of forming a swarm as "rapid multiplication", and compared this to swarm formation by "species aggregating" in *E. superba* or *T. gaudichaudii*.

T. gaudichaudii showed no clear diurnal migration patterns except on one night station in the northern Bellingshausen Sea (Station 1121), where large numbers (810 ind./1000 m³) were collected by the upper RMT 8 (65–0 m). This behaviour verified its habit of forming surface swarms as reported by KANE (1966) and EVERSON and WARD (1980). No diurnal migration patterns were obtained for *E. crystallorophias*, *T. macrura*, chaetognaths and siphonophores, since their numerical abundances did not vary significantly between day and night.

The various surface waters off the Antarctic Peninsula are characterized by distinctly different species compositions in the macrozooplanktonic-micronektonic size groupings.

E. frigida, *E. triacantha* and *S. thompsoni*, the three species with an obvious diurnal migration pattern, preferred the surface waters of the southern Drake Passage and the Scotia Sea. *E. superba* was most abundant in surface waters influenced by Weddell Sea water, which *T. gaudichaudii* largely avoided. *E. crystallorophias* occurred mostly in the nearshore regions, which were characterized by Bellingshausen Sea water or Weddell Sea water. All taxa were present in surface waters governed by water masses of Bellingshausen Sea origin.

However, in the light of the presented data it cannot be assumed that any of the species discussed can be considered as an "indicator species" for a specific water mass, despite some characteristic features.

Acknowledgements

I wish to thank all scientists who carried out the RMT-sampling programme as well as the "John Biscoe" crew, who supported the field work with unrelenting enthusiasm, ELKE MIZDALSKI and many of her colleagues for sorting the large number of RMT 8 samples and Dr. R. B. HEYWOOD for providing his unpublished hydrographic data. I am very grateful to Drs. S. B. SCHNACK and G. S. DIECKMANN who read the manuscript and made valuable suggestions for its improvement.

References

- ALVARIÑO, A., 1981: Siphonophorae [in Spanish]. In: BOLTOVSKOY, D. (ed.): Atlas del Zooplancton del Atlántico Sudoccidental. Publicación especial del INIDEP, Mar del Plata, Argentina. 383–441.
- ANON., 1983a: First Post-FIBEX Hydrographic Data Interpretation Workshop, Hamburg, F.R.G., 20–26 September 1982. Pol. Polar Res. 4, 155–162.
- ANON., 1983b: Second Post-FIBEX Hydrographic Data Interpretation Workshop, Hamburg, F.R.G., 16–20 May 1983. BIOMASS Rep. Ser. 31, 1–26.
- BAKER, A. DE C., 1959: The distribution and life history of *Euphausia triacantha* Holt and Tattersall. Discovery Rep. 29, 309–340.
- BARNARD, K. H., 1932: Amphipoda. Discovery Rep. 5, 1–326.
- BOWMAN, T. E.; GRUNER, H. E., 1973: The Families and Genera of Hyperiidæ (Crustacea: Amphipoda). Smithsonian Contrib. Zoology 146, 1–64.
- CLOWES, A. J., 1934: Hydrology of the Bransfield Strait. Discovery Rep. 9, 1–64.
- DAVID, P. M., 1958: The distribution of the Chaetognatha of the Southern Ocean. Discovery Rep. 29, 200–229.
- DEACON, G. E. R., 1937: The hydrology of the Southern Ocean. Discovery Rep. 15, 1–124.
- DINOFRIO, E. O., 1977: Resultados planctológicos de la campaña "Oceantar I". IV – Anfipodos Hipéridos [in Spanish]. Contr. Inst. Ant. Arg. 214, 1–28.
- ESNAL, G. B., 1981: Thaliacea: Salpidae [in Spanish]. In: BOLTOVSKOY, D. (ed.): Atlas del Zooplancton del Atlántico Sudoccidental. Publicación especial del INIDEP, Mar del Plata, Argentina, pp. 793–808.
- EVERSON, I., 1982: Diurnal variations in mean volume backscattering strength of an Antarctic krill (*Euphausia superba*) patch. J. Plankt. Res. 4, 155–162.

- EVERSON, I., 1984: Zooplankton. In: LAWS, R. M. (ed.): Antarctic Ecology. London, New York: Academic Press 2, 463-490.
- EVERSON, I.; WARD, P., 1980: Aspects of Scotia Sea zooplankton. Biol. J. Linnean Soc. 14, 93-101.
- FOXTON, P., 1966: The distribution and life history of *Salpa thompsoni* Foxton with observations on a related species *Salpa gerlachei* Foxton. Discovery Rep. 34, 1-116.
- HAGEN, W., 1985: On distribution and population structure of Antarctic Chaetognatha. Meeresforsch., this volume.
- HARBISON, G. R.; MCALISTER, V. L., 1979: The filter-feeding rates and particle retention efficiencies of three species of *Cyclosalpa* (Tunicata, Thaliacea). Limnol. Oceanogr. 24, 875-892.
- HARDY, A. C.; GUNTHER, E. R., 1936: The plankton of the South Georgia whaling grounds and adjacent waters. Discovery Rep. 11, 1-456.
- HEMPER, G.; HEYWOOD, R. B., 1982: Joint Biological Expedition on RRS "John Biscoe", February 1982. Ber. Polarforsch. 5, 1-39.
- HEYWOOD, R. B., 1985: Environmental conditions in the Antarctic Peninsula area of the Southern Ocean during the Anglo-German Joint Biological Expedition, February 1982. Meeresforsch., this volume.
- HOPKINS, T. L., 1985: The Zooplankton Community of Croker Passage, Antarctic Peninsula. Polar Biol. 4, 161-170.
- JOHN, D. D., 1936: The southern species of the genus *Euphausia*. Discovery Rep. 14, 195-323.
- KANE, J. E., 1966: The distribution of *Parathemisto gaudichaudii* (Guer.) with observations on its life history in the 0° to 20° E Sector of the Southern Ocean. Discovery Rep. 34, 163-198.
- KIRKWOOD, J. M., 1982: A Guide to the Euphausiacea of the Southern Ocean. ANARE Res. Notes 1, 1-45.
- KITTEL, W., 1980: Populational studies on *Euphausia superba* Dana 1852 (Euphausiacea, Crustacea) in waters of the Admiralty Bay during Antarctic summer of 1978. Pol. Arch. Hydrobiol. 27, 267-272.
- MACKINTOSH, N. A., 1934: Distribution of the macroplankton in the Atlantic sector of the Antarctic. Discovery Rep. 9, 67-160.
- MAUCHLINE, J., 1980: Key for the Identification of Antarctic Euphausiids. BIOMASS Handbook 5, 1-14.
- MILLER, D. G. M., 1985: Marine Macro-Plankton of Two Sub-Antarctic Islands. In SIEGFRIED, R. W.; CONDY, P. R.; LAWS, R. M. (eds.): Antarctic nutrient cycles and food webs. Proc. 4th SCAR Symp. Antarct. Biol., Berlin, Heidelberg, New York, Springer, pp. 355-361.
- MOSER, F., 1925: Die Siphonophoren der Deutschen Südpolar-Expeditionen 1901-1903 [in German]. In DRYGALSKI, E. v. (ed.): Deutsche Südpolar-Expedition 1901-1903. XVII. Band, Zoologie IX. Band, 1-541.
- O'SULLIVAN, D., 1983: A Guide to the Pelagic Tunicates of the Southern Ocean and Adjacent Waters. ANARE Res. Notes 8, 1-98.
- PIATKOWSKI, U., 1983: Joint Biological Expedition on RRS "John Biscoe", February 1982 (II). Data of micronection and zooplankton hauls. Ber. Polarforsch. 11, 1-40.
- PIATKOWSKI, U., 1985: Maps of the Geographical Distribution of Macrozooplankton in the Atlantic Sector of the Southern Ocean. Ber. Polarforsch. 22, 1-55.
- ROE, H. S. J.; SHALE, D. M., 1979: A New Multiple Rectangular Midwater Trawl (RMT 1 + 8 M) and Some Modifications to the Institute of Oceanographic Sciences' RMT 1 + 8. Mar. Biol. 50, 283-288.
- ROE, H. S. J.; BAKER, A. DE C.; CARSON, R. M.; WILD, R.; SHALE, D. M., 1980: Behaviour of the Institute of Oceanographic Sciences' Rectangular Midwater Trawls: Theoretical Aspects and Experimental Observations. Mar. Biol. 56, 247-259.
- SIEGEL, V., 1985: The distribution pattern of krill, *Euphausia superba*, west of the Antarctic Peninsula in February 1982. Meeresforsch., this volume.
- TRANter, D. J., 1982: Interlinking of Physical and Biological Processes in the Antarctic Ocean. Oceanogr. Mar. Biol. Ann. Rev. 20, 11-36.
- WEIGMANN-HAASS, R.; HAASS, G., 1980: Geographische Verbreitung und vertikale Verteilung der Euphausiacea (Crustacea) während der Antarktis-Expedition 1975/76 [in German]. Meeresforsch. 28, 19-31.
- WITEK, Z.; KITTEL, W.; ZMIJEWSKA, I.; CZYKIETA, H.; PRESLER, E., 1984: Macrozooplankton in the southern Drake Passage and in the Bransfield Strait during early summer of 1983/1984/BIOMASS-SIBEX. Coun. Meet. ICES Biol. Oceanogr. Cttee. C. M. L.: 32, 1-18.
- YOUNGBLUTH, M. J., 1976: Vertical distribution and diel migration of euphausiids in the central region of the California current. Fish. Bull. U.S. 74, 925-936.

Author's address: UWE PIATKOWSKI, Alfred-Wegener-Institut für Polarforschung, Columbus-Center, D-2850 Bremerhaven, Federal Republic of Germany